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THE APPLIED IMPORTANCE OF RESEARCH ON THE MATCHING LAW

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In this essay, we evaluate the applied implications of two articles related to the matching law and published in the *Journal of the Experimental Analysis of Behavior,* May 1994. Building on Mace's (1994) criteria for increasing the applied relevance of basic research, we evaluate the applied implications of basic research studies. Research by Elsmore and McBride (1994) and Savastano and Fantino (1994) involve an extension of the behavioral model of choice. Elsmore and McBride used rats as subjects, but arranged a multioperant environment that resembles some of the complex contingencies of human behavior. Savastino and Fantino used human subjects and extended the matching law to ratio and interval contingencies. These experiments contribute to a growing body of knowledge on the matching law and its relevance for human behavior.

DESCRIPTORS: choice, matching law, application, concurrent schedules

The May issue of the *Journal of the Experimental Analysis of Behavior* (*JEAB*) included a position paper by Mace (1994) pointing to the need for basic research with greater ecological and external validity in relation to human behavior. Building on previous commentary and analysis, Mace recommended a three-step approach to increase the applied relevance of basic research. The approach includes the development of animal models of important human problems, extending the modeled relations to humans (i.e., experimental analysis of human behavior), and testing the generality of these relations with human problems in everyday settings. At the present time, it is difficult to find examples of Mace's three-step approach in the behavior analysis literature (but see Pierce & Epling, 1994, for activity anorexia, and McDowell, 1988, for the matching law).

Mace's suggestions may, however, be slightly modified and then used to evaluate the practical importance of basic research. In this essay, we evaluate the applied implications of two articles published in *JEAB,* May 1994, that focused on the matching law. These criteria offer a strategy for judging the practical importance of basic research. It seems plausible that the practical importance of any basic experiment increases as it fulfills more and more of these criteria.

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Matching and Response Allocation

Mace (1994) points to the applied relevance of research on response allocation and the matching law (Baum, 1974; Herrnstein, 1961). Two articles in the May issue of *JEAB* have implications for the analysis and modification of human choice behavior in everyday life. Elsmore and McBride (1994) and Savastano and Fantino (1994) both raise questions about the generality of the matching law. In order to assess the applied importance of these articles, it is necessary to place them in the context of other related experiments.

There is strong evidence that pigeons (and other nonhuman organisms) presented with concurrent variable-interval schedules (VI VI) of reinforcement allocate behavior in accord with the distribution of reinforcement. In this situation, relative rate of response matches (equals) relative rate of reinforcement (Davison & McCarthy, 1988; de Villiers, 1977). In terms of application, concurrent schedules of reinforcement model complex environments in which humans are faced with choosing between

alternative courses of action. For example, Conger and Killeen (1974) assessed human performance in a group discussion situation. Talking was reinforced by two listeners on a concurrent VI VI schedule with brief positive words or phrases. Relative time spent talking to a listener matched relative rate of social reinforcement from that listener. This study and others (e.g., McDowell, 1988) showed that the basic research on concurrent schedules and matching with nonhumans generalizes to everyday human behavior.

In terms of generality, the matching law is a good description of human behavior on concurrent VI VI schedules in laboratory settings (Pierce & Epling, 1983). McDowell (1988) showed that matching theory generalizes to natural human environments and has implications for the modification of human behavior (see also Myerson & Hale, 1984). At the present time, a few applied studies have found that the matching law predicts socially important behavior on concurrent variable-ratio (VR VR) schedules (Mace, McCurdy, & Quigley, 1990) and on concurrent VI VI schedules (Conger & Killeen, 1974; Martens & Houk, 1989; Martens, Lochner, & Kelly, 1992), although recent studies suggest limitations. For example, students in a special education program approximated matching on concurrent VI VI schedules, but only when timers signaled the intervals on the operating schedules or were used in preliminary training (Neef, Mace, & Shade, 1993; Neef, Mace, Shea, & Shade, 1992). Also, departures from matching may be expected in applied settings when quality of, and delayed access to, reinforcement are varied (Neef et al., 1993).

Although basic research on concurrent schedules and matching is relevant to human problems, researchers continue to question the generalizability of basic animal experiments (Mace, 1994; Pierce & Epling, 1991). For example, Neef et al. (1992) and Mace (1994) note that most of the laboratory research with pigeons and humans uses symmetrical-choice procedures. Mace indicates that "the vast majority of research on concurrent schedules has involved symmetrical choices . . . between alternatives that differ only in the rate of reinforcement each alternative produces, while the reinforcers, response manipulanda, and delays to reinforcement are held constant" (1994, p. 533). In everyday settings, humans are faced with alternatives that arrange qualitatively different reinforcers and that require different forms of response after varying delays. For example, a person may choose among television channels offering qualitatively different programs that schedule entertaining events on a random-interval basis. Experiments that introduce procedures that depart from standard concurrent VI VI food reinforcement schedules test the matching law in novel situations. To the extent that variation in the experimental procedures models the complexity of human environments, the relevance of matching as a description of human behavior is potentially increased.

Matching in a Multioperant Environment

Elsmore and McBride (1994) reported two experiments on the matching law. These experiments introduce new procedures that begin to model the complexity of the natural environment. Rats were required to search for food in an eight-arm radial maze. The maze consisted of a central platform with eight straight arms that extend from the central area. Standard pellet feeders were connected to the end of each arm, and the rats could choose to enter any of the arms to obtain food. Food was available on eight independent concurrent interval schedules—fixed-interval schedules in Experiment 1 and random-interval schedules in Experiment 2. Rates of reinforcement for the eight schedules varied between 65 and 5 reinforcers per hour. Some conditions were run with a changeover delay (COD) contingency in effect, and others omitted this contingency.

In terms of procedure, Elsmore and McBride (1994) present a situation that begins to contact some of the features found in human environ-

ments. People typically are able to choose among many alternative sources of reinforcement that require a change in location in order to obtain reinforcement. In a library, a person chooses among many different books located in different places of the building. In terms of application, this research implies that the architecture and physical arrangement of objects and materials will be important determinants of behavior allocation. Also, human situations seldom set up contingencies like the COD; it is therefore interesting to find out what happens when this requirement is eliminated in a complex environment. Finally, the researchers measured searching for (number of entries into an arm of the maze) and procurement of (both time spent in an arm and responses for food) reinforcement. This is similar to finding the locations of clothing stores in a shopping mall. Each store is a different arm of the maze, and the shopper is free to go from one store to another. Once in the store, reinforcing items are found on an intermittent schedule. Elsmore and McBride's experiment raises the question of whether these two performances (finding the location vs. shopping for items) are regulated by the same principles.

In general, results from these experiments support the extension of the matching law to situations involving many alternative sources of reinforcement. In the absence of the COD, responses for reinforcement (procurement) were well described by Baum's (1974) generalized matching equation. This indicates that relative rate of reinforcement determines behavior in complex settings, even when procedures are eliminated that favor matching.

This overall conclusion is tempered by the finding that searching for reinforcement was not as well described by the matching law as was behavior that directly produced reinforcement (procurement). Apparently, behavior that is closer to reinforcement is more sensitive to relative rate of reinforcement than responses that are more distant. As a speculation, a shopper's entries into clothing stores may not be as sensitive to relative rates of reinforcement as when the shopper is selecting items on different racks within the store.

Human Matching on a Concurrent Interval-Ratio Schedule

Savastano and Fantino (1994) also investigated the matching law, but in a situation that favored optimal performance. Economic theories of choice (maximization) often assume that humans are rational actors who consciously attempt to minimize cost and maximize benefits. Behavioral theories (including the matching law) emphasize the role of contingencies of reinforcement as a determinant of choice behavior. Savastano and Fantino asked whether human performance is best described by matching or by maximizing.

Matching occurs when a person distributes behavior in accord with the relative rates of reinforcement. Maximizing requires that an individual shift between alternative sources of reinforcement in a way that yields the greatest overall payoff (optimal performance). In order to evaluate the experimental question, Savastano and Fantino arranged a situation in which matching relative rates of reinforcement would lower the overall payoff. That is, a person who distributed behavior in terms of the matching law would necessarily behave in a suboptimal manner.

Undergraduate students faced a panel and pressed a button to change from one schedule of monetary reinforcement to another. The schedules of reinforcement were similar to VI and VR schedules, but controlled for rate of response. When given a choice between different values of VI and VR schedules of reinforcement, a person would obtain the maximum payoff by spending most of the time on the ratio alternative and occasionally sampling the interval schedule. This maximizing strategy takes advantage of the fact that the interval schedule continues to advance even when the person is spending time on the ratio alternative. In contrast, the ratio schedule pays off only

when the person spends time on that schedule. A person who distributed behavior in accord with the relative rates of reinforcement (matching) would spend more time on the interval alternative than is predicted by maximization.

Results showed that, in general, human performance is not well described by a maximization account of behavior. Human subjects spent more time on the interval schedule than was required to obtain the maximum overall payoff. The performance of humans was more in accord with the matching law. Baum's (1974) generalized matching equation was applied to the time spent on the ratio and interval alternatives. The grouped data for all subjects approximated matching of time spent to the relative rates of reinforcement. These results, however, should be interpreted with caution because the data showed considerable between-subject variability.

Savastano and Fantino's (1994) experiment supports the applied significance of the matching law as presented by Myerson and Hale (1984). Myerson and Hale considered the implications of schedule control of target behavior when the maintenance schedule for that behavior is unknown. One part of their analysis concerned a situation in which the target behavior is maintained by unidentified ratio contingencies (i.e., the ratio requirement is unknown). In an applied setting, the target behavior often occurs at high frequency and is considered to be a problem. In order to reduce the probability of a response, Myerson and Hale suggest programming reinforcement for alternative behavior on an interval schedule. According to the matching law, the target behavior must be reduced because of the shift in relative rate of reinforcement; this analysis is supported by Savastano and Fantino's experiment. Of course, a ratio schedule for alternative behavior could also be used, but it may not work, because the richer alternative, on a concurrent ratio schedule, captures all the behavior in the situation (exclusive preference). The intervention will be a total success if the ratio schedule for alternative behavior is richer than the maintenance schedule, but the intervention will be a complete failure if it is not.

Evaluation of Applied Importance

The applied importance of the experiments by Elsmore and McBride (1994) and Savastano and Fantino (1994) may be assessed according to the criteria suggested in the first section this paper. Both experiments involve an extension of the behavioral model of choice. Elsmore and McBride used rats, but arranged a multioperant environment that more closely models the contingencies of human behavior. Savastino and Fantino used human subjects and extended the matching law to ratio and interval contingencies. Again, this experiment begins to model the operating schedules in everyday settings.

Both experiments contribute to a growing body of knowledge on the matching law and its relevance for human behavior (Davison & McCarthy, 1988; de Villiers, 1977; Pierce & Epling, 1983). In this regard, any one experiment has less applied importance than the body of research to which it contributes. As more and more basic research confirms and extends the generality of the matching law, applied behavior analysts can have greater confidence that behavioral theories of choice strongly determine human behavior. This observation implies that behavior analysts weigh the applied relevance of any experiment within the context of other research.

The two experiments highlighted in this paper have increased importance for applied behavior analysis because a few studies have used the matching law for modification of problem behavior. For example, McDowell (1981, 1982) reported the use of matching theory to treat a mildly retarded man's aggression, noncompliance, and temper tantrums. Token reinforcement was arranged for unrelated alternative behavior, which resulted in a substantial reduction in oppositional behavior. Since these early reports, other studies have used the matching law to analyze and modify on-task and disruptive behavior of a retarded girl (Martens & Houk,

1989) and students' academic behavior (Martens et al., 1992; Neef et al., 1992). These studies show that the matching law is useful in applied settings and suggest that basic research extensions of the law may contribute to more powerful applications.

REFERENCES

Baum, W. M. (1974). On two types of deviation from the matching law: Bias and undermatching. *Journal of the Experimental Analysis of Behavior, 22,* 231–242.

Conger, R., & Killeen, P. (1974). Use of concurrent operants in small group research. *Pacific Sociological Review, 17,* 399–416.

Davison, M., & McCarthy, D. (1988). *The matching law: A research review.* Hillsdale, NJ: Erlbaum.

de Villiers, P. A. (1977). Choice in concurrent schedules and a quantitative formulation of the law of effect. In W. K. Honig & J. E. R. Staddon (Eds.), *Handbook of operant behavior* (pp. 233–287). Englewood Cliffs, NJ: Prentice-Hall.

Elsmore, T. F., & McBride, S. A. (1994). An eight-alternative concurrent schedule: Foraging in a radial maze. *Journal of the Experimental Analysis of Behavior, 61,* 331–348.

Herrnstein, R. J. (1961). Relative and absolute strength of response as a function of frequency of reinforcement. *Journal of the Experimental Analysis of Behavior, 4,* 267–272.

Mace, F. C. (1994). Basic research needed for stimulating the development of behavioral technologies. *Journal of the Experimental Analysis of Behavior, 61,* 529–550.

Mace, F. C., McCurdy, B., & Quigley, E. (1990). A collateral effect of reward predicted by matching theory. *Journal of Applied Behavior Analysis, 23,* 197–205.

Martens, B. K., & Houk, J. L. (1989). The application of Herrnstein's law of effect to disruptive and on-task behavior of a retarded adolescent girl. *Journal of the Experimental Analysis of Behavior, 51,* 17–27.

Martens, B. K., Lochner, D. G., & Kelly, S. Q. (1992). The effects of variable-interval reinforcement on academic engagement: A demonstration of matching theory. *Journal of Applied Behavior Analysis, 25,* 143–151.

McDowell, J. J. (1981). On the validity and utility of Herrnstein's hyperbola in applied behavior analysis. In C. M. Bradshaw, E. Szabadi, & C. F. Lowe (Eds.), *Quantification of steady-state operant behaviour* (pp. 311–324). Amsterdam: Elsevier/North-Holland.

McDowell, J. J. (1982). The importance of Herrnstein's mathematical statement of the law of effect for behavior therapy. *American Psychologist, 37,* 771–779.

McDowell, J. J. (1988). Matching theory in natural human environments. *The Behavior Analyst, 11,* 95–108.

Myerson, J., & Hale, S. (1984). Practical implications of the matching law. *Journal of Applied Behavior Analysis, 17,* 367–380.

Neef, N. A., Mace, F. C., & Shade, D. (1993). Impulsivity in students with serious emotional disturbances: The interactive effects of reinforcer rate, delay, and quality. *Journal of Applied Behavior Analysis, 26,* 37–52.

Neef, N. A., Mace, F. C., Shea, M. C., & Shade, D. (1992). Effects of reinforcer rate and reinforcer quality on allocation of academic behavior. *Journal of Applied Behavior Analysis, 25,* 657–664.

Pierce, W. D., & Epling, W. F. (1983). Choice, matching and human behavior: A review of the literature. *The Behavior Analyst, 6,* 57–76.

Pierce, W. D., & Epling, W. F. (1991). Can operant research with animals rescue the science of human behavior. *The Behavior Analyst, 14,* 129–132.

Pierce, W. D., & Epling, W. F. (1994). Activity anorexia: An interplay between basic and applied behavior analysis. *The Behavior Analyst, 17,* 7–24.

Savastano, H. I., & Fantino, E. (1994). Human choice in concurrent ratio-interval schedules of reinforcement. *Journal of the Experimental Analysis of Behavior, 61,* 453–463.

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